WT-915

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OPERATION CASTLE

Project 2.5a

DISTRIBUTION AND INTENSITY OF FALLOUT

REPORT TO THE SCIENTIFIC DIRECTOR

by

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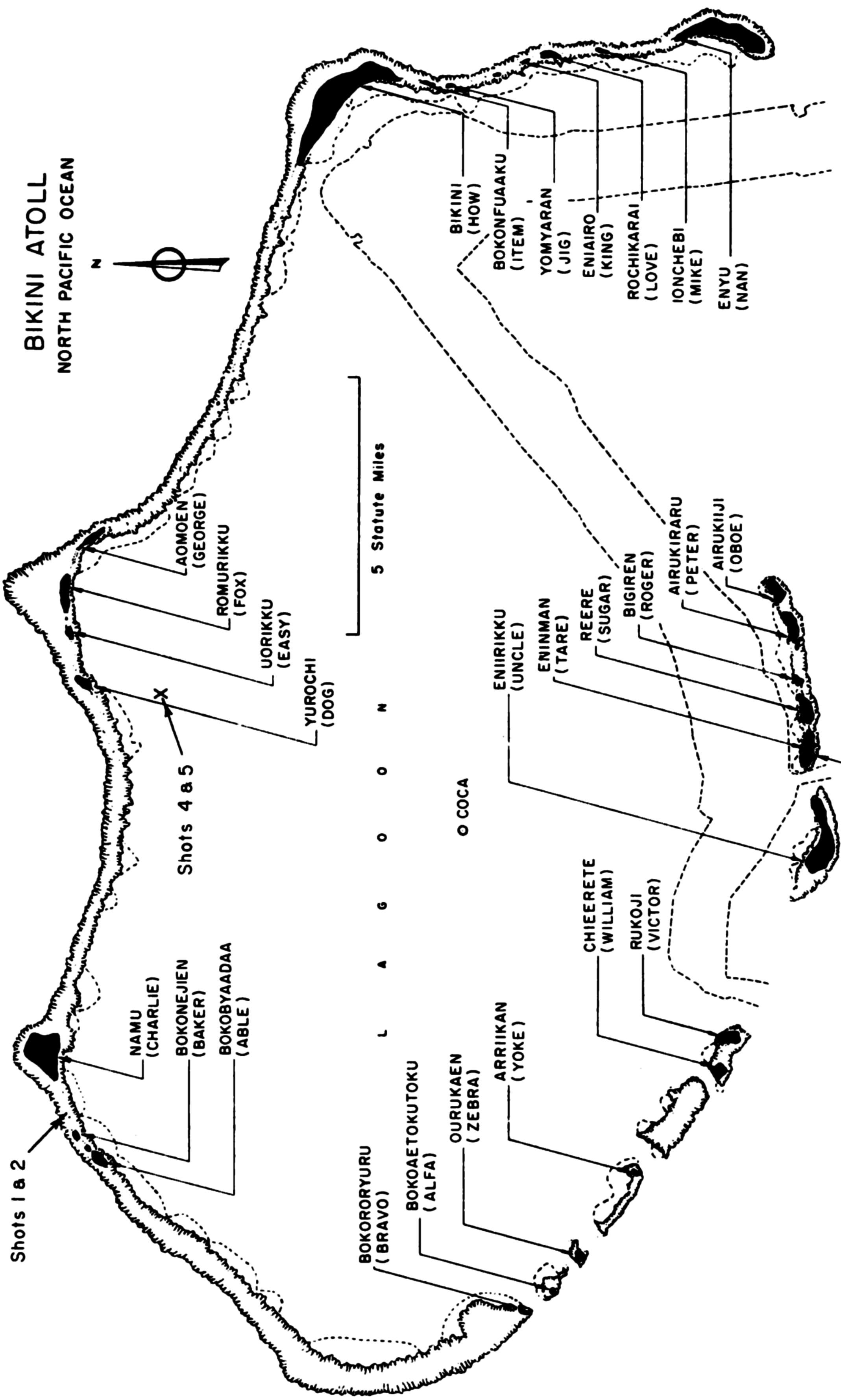
BIKINI ATOLL
NORTH PACIFIC OCEAN
N
5 Statute Miles
L A G O O N
O COCA
Shots 1 a 2
Shots 4 a 5
Shot 3
NAMU (CHARLIE)
BOKONEJIEN (BAKER)
BOKOBYAADAA (ABLE)
AOMOEN (GEORGE)
ROMURIKKU (FOX)
UORIKKU (EASY)
YUROCHI (DOG)
BIKINI (HOW)
BOKONFUAAKU (ITEM)
YOMYARAN (JIG)
ENIAIRO (KING)
ROCHIKARAI (LOVE)
IONCHEBI (MIKE)
ENYU (NAN)
AIRUKIIJI (OBOE)
AIRUKIRARU (PETER)
BIGIREN (ROGER)
REERE (SUGAR)
ENINMAN (TARE)
ENIIRIKKU (UNCLE)
CHIEERETE (WILLIAM)
RUKOJI (VICTOR)
ARRIIKAN (YOKE)
OURUKAEN (ZEBRA)
BOKOAETOKUTOKU (ALFA)
BOKORORYURU (BRAVO)

GENERAL SHOT INFORMATION

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
DATE	1 March	27 March	7 April	26 April	5 May	14 May
CODE NAME (Unclassified)	Bravo	Romeo	Koon	Union	Yankee	Nectar
TIME*	06:40	06:25	06:15	06:05	06:05	06:15
LOCATION	Bikini, West of Charlie (Namu) on Reef	Bikini, Shot 1 Crater	Bikini, Tare (Eninman)	Bikini, on Barge at Intersection of Arcs with Radii of 6900' from Dog (Yurochi) and 3 Statute Miles from Fox (Aomoen).		Eniwetok, IVY Mike Crater, Flora (Elugelab)
TYPE	Land	Barge	Land	Barge	Barge	Barge
HOLMES & NARVER COORDINATES	N 170,617.17 E 76,163.98	N 170,635.05 E 75,950.46	N 100,154.50 E 109,799.00	N 161,698.83 E 116,800.27	N 161,424.43 E 116,688,15	N 147,750.00 E 67,790.00

* APPROXIMATE

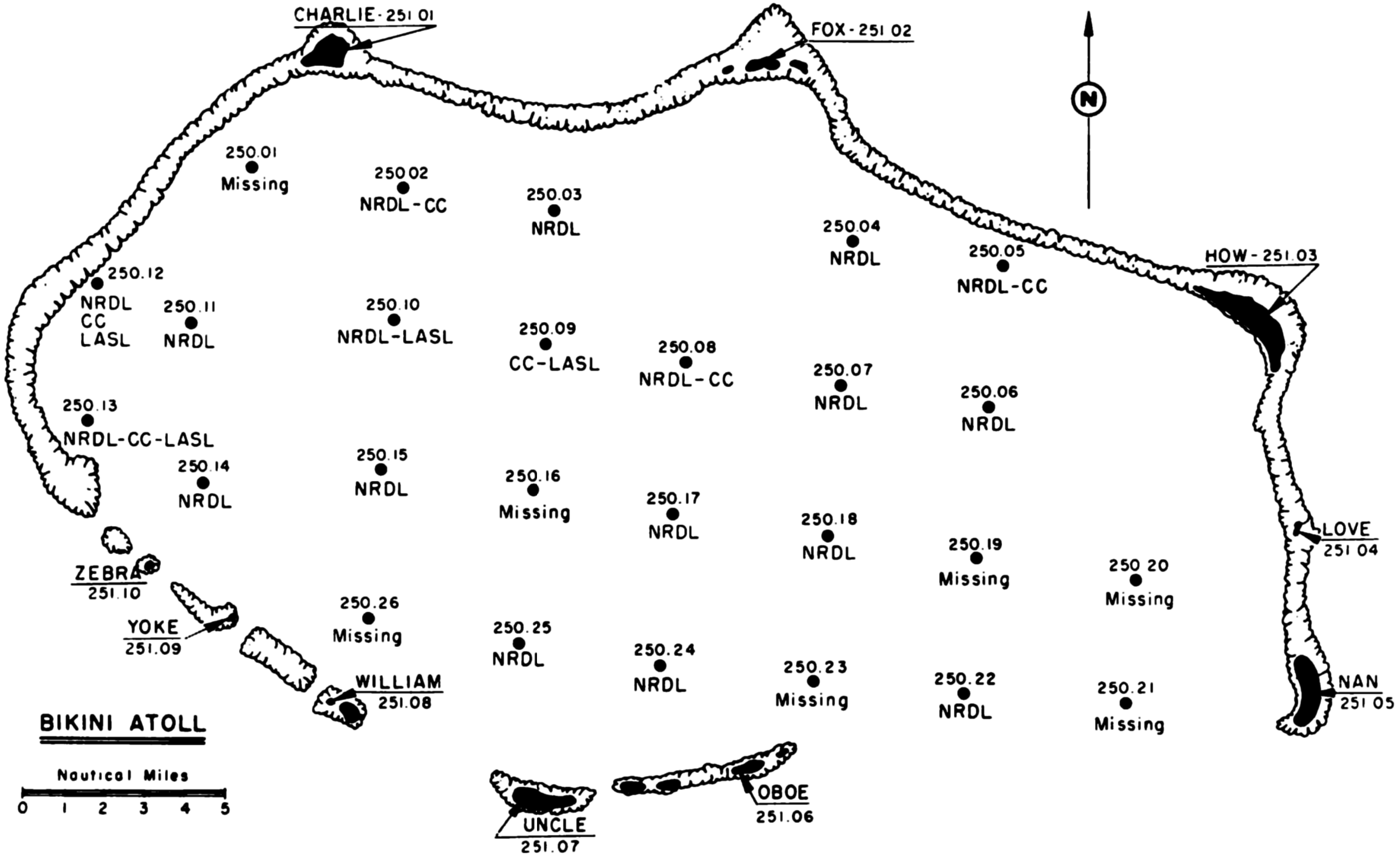

Fig. 2.2 Lagoon and Island Station Array for Bikini Atoll

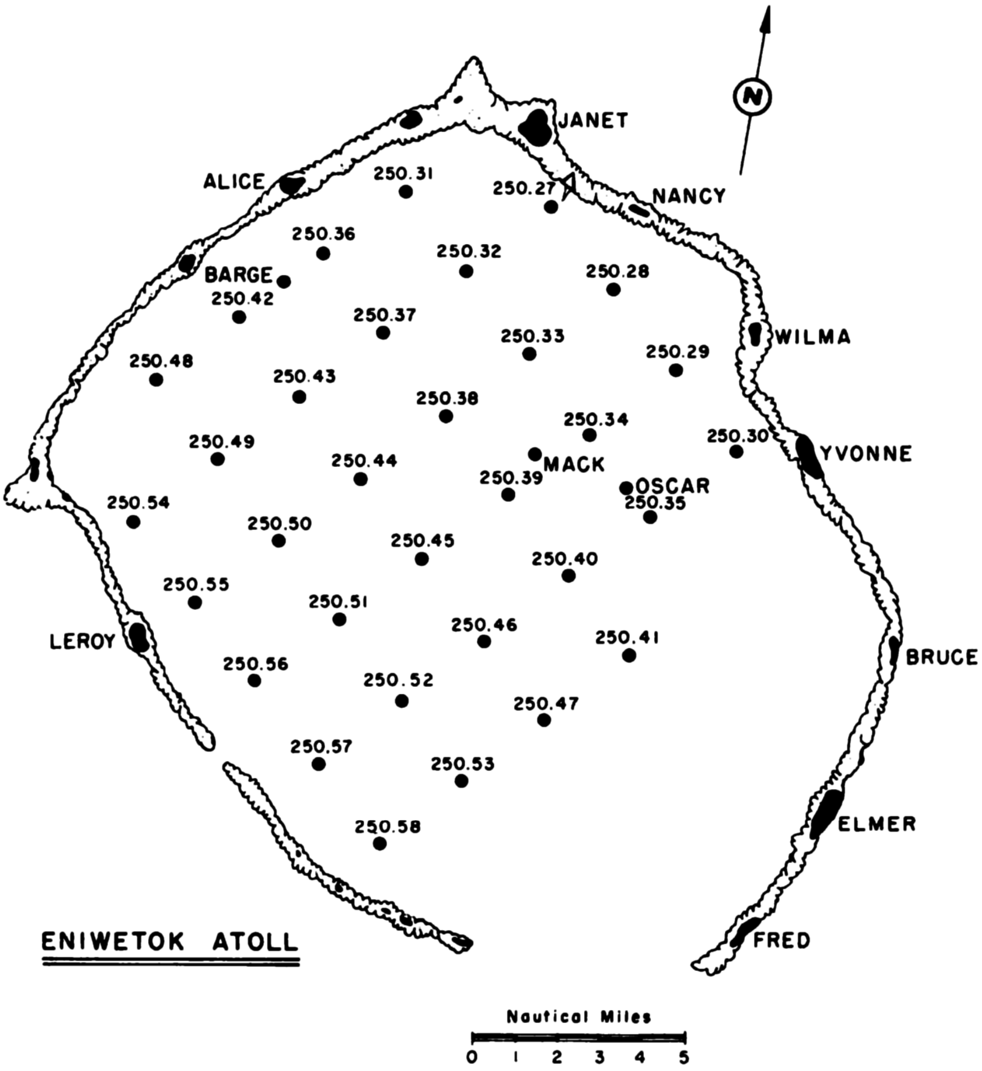

Fig. 2.3 Lagoon Array for Eniwetok Atoll

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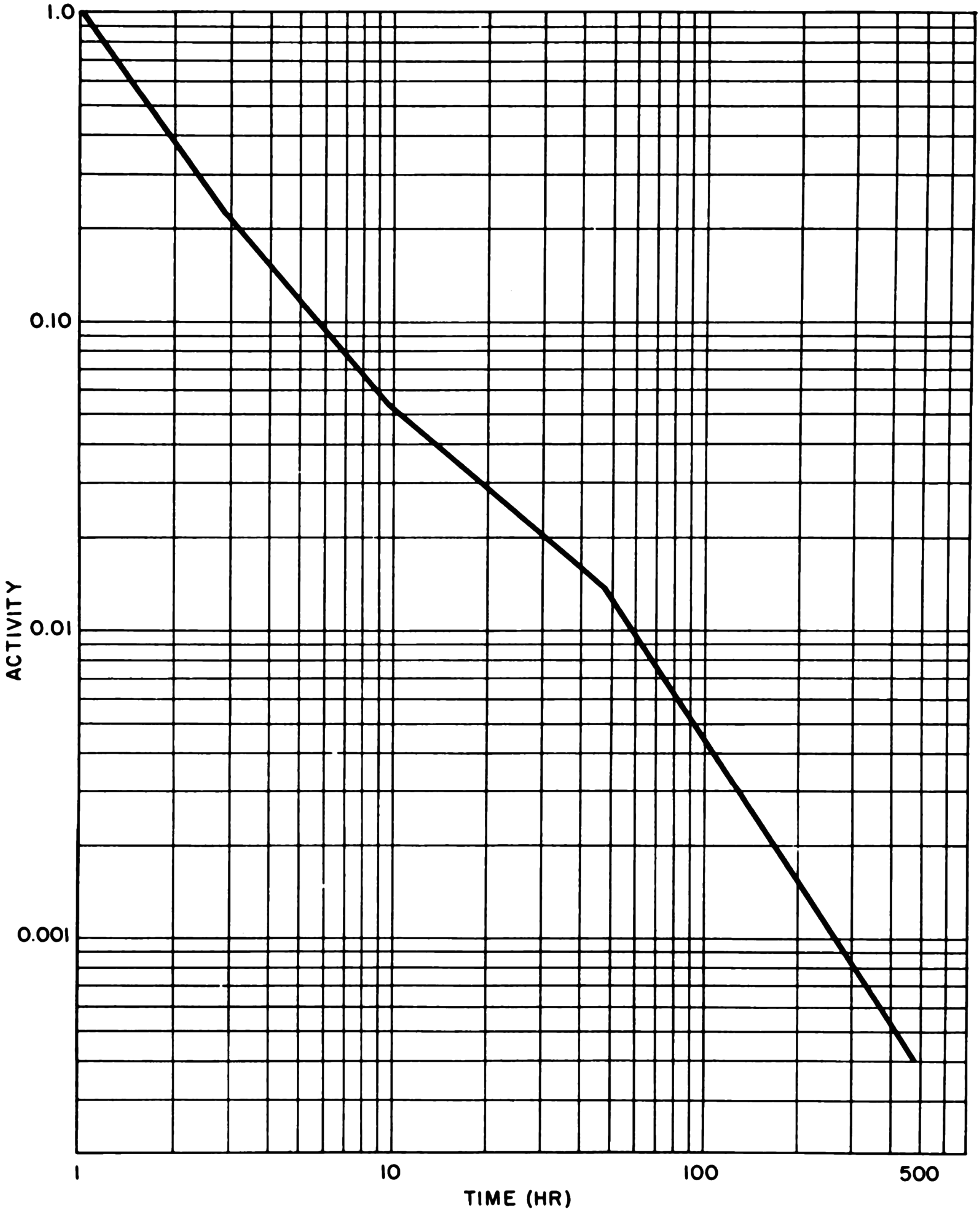


Fig. 5.3 Composite Gamma Ionization Decay Curve

No samples suitable for particle analysis were obtained from Shot 3. Following Shot 1, 6971 radioactive particles were analyzed from the area within the Bikini Atoll and 621 particles collected on the outer atolls of Ailinginae, Rongelap, and Utirik were evaluated. The differential fallout collector on the island of Alice contained some particulate from Shot 6. These data are also presented.

5.2.1 Shot 1, Close-in Fallout

The size distribution of close-in fallout particles with respect to time for four lagoon and three island stations are given in Appendix C. Only radioactive particles are included in the data. Of the 40 available sampling increments within each differential collector, those increments that visually appeared to contain a large amount of particulate were selected for analysis. Increments over a wide time period were likewise selected. Analysis of the bar graphs with respect to rate of arrival or time of arrival is therefore an approximation. Data on time of arrival are presented in Section 5.6 of this report.

Figure 5.4 shows the size frequency distribution of the Shot 1 close-in particulate. It is a composite of the bar graphs for the four lagoon and three island stations. (Figs. C-1 through C-7.)

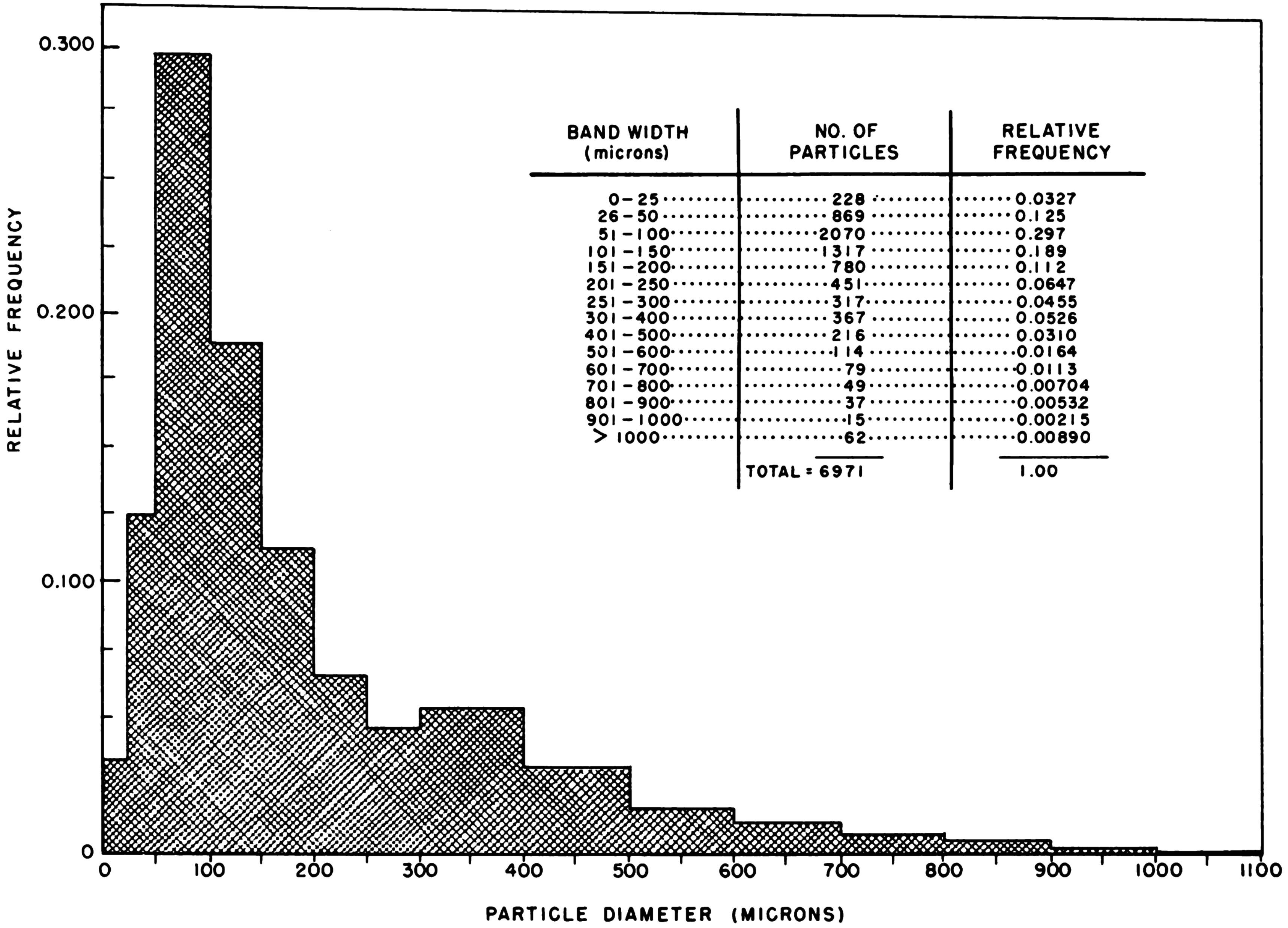
Figure 5.5 is a plot of the cumulative size distribution of Shot 1 particulate presented on a log probability graph. The size distribution is very close to log normal with a geometric mean particle diameter of 112 μ.

5.2.2 Shot 1, Outer Island Fallout

Samples of earth were collected by the outer island survey team following Shot 1.[15] The radioactive particulate found in these soil samples was analyzed for size distribution and the results are presented in Fig. 5.6. These atolls were 70 to 280 nautical miles from Shot 1. Figure 5.7 shows a log normal size distribution for particles collected on three atolls. The geometric mean particle diameters are presented in Table 5.4.

TABLE 5.4 - Geometric Mean Particle Diameter

Atoll	Distance from Shot Point (n mi)	Geometric Mean Particle Diameter (μ)
Bikini	10	112
Ailinginae	70	60
Rongelap	107	70
Utirik	277	45



BAND WIDTH (microns)	NO. OF PARTICLES	RELATIVE FREQUENCY
0 – 25	228	0.0327
26 – 50	869	0.125
51 – 100	2070	0.297
101 – 150	1317	0.189
151 – 200	780	0.112
201 – 250	451	0.0647
251 – 300	317	0.0455
301 – 400	367	0.0526
401 – 500	216	0.0310
501 – 600	114	0.0164
601 – 700	79	0.0113
701 – 800	49	0.00704
801 – 900	37	0.00532
901 – 1000	15	0.00215
> 1000	62	0.00890
	TOTAL = 6971	1.00

Fig. 5.4 Shot 1, Composite Particle Size Distribution

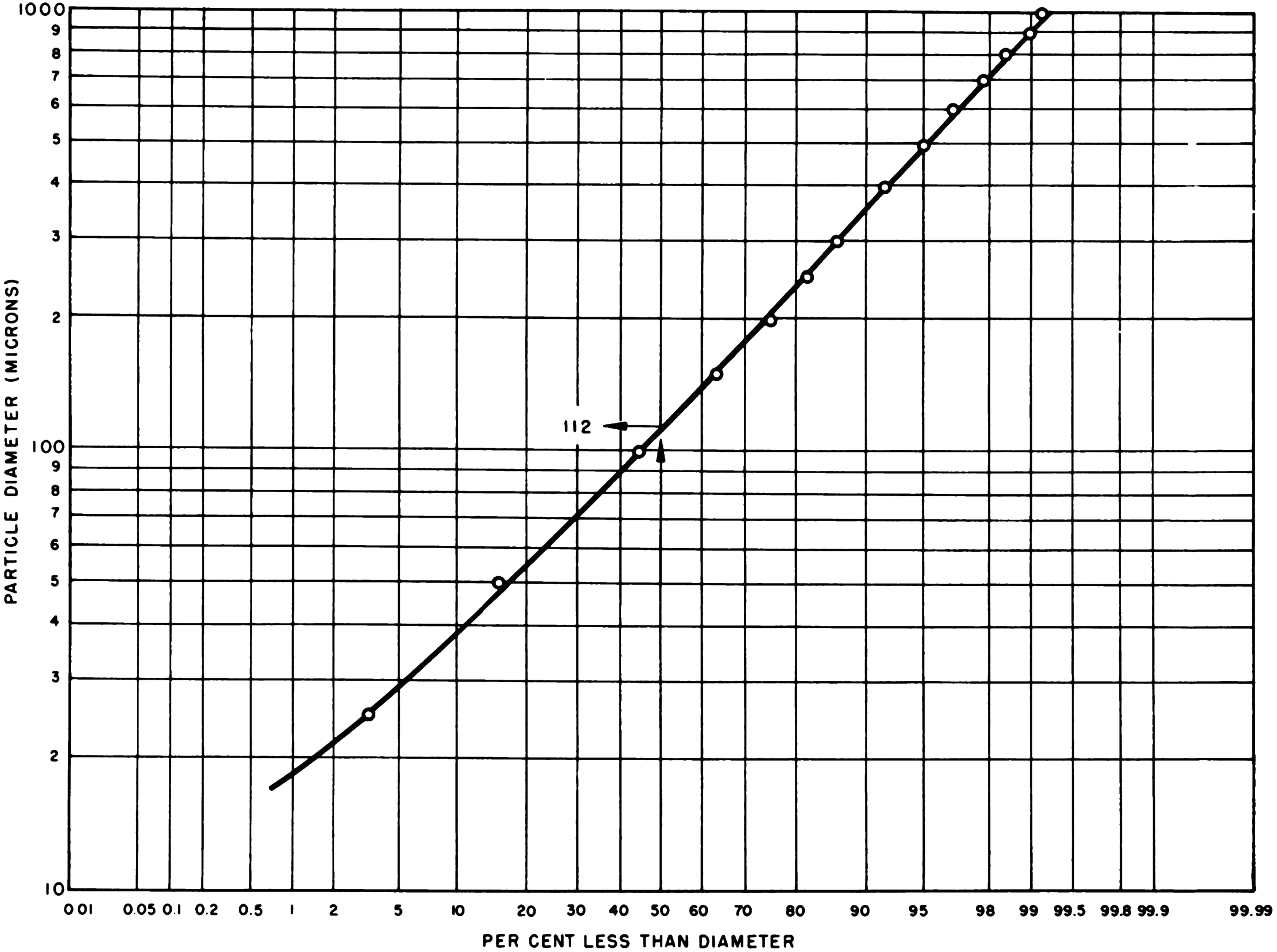


Fig. 5.5 Shot 1, Cumulative Particle Size Distribution

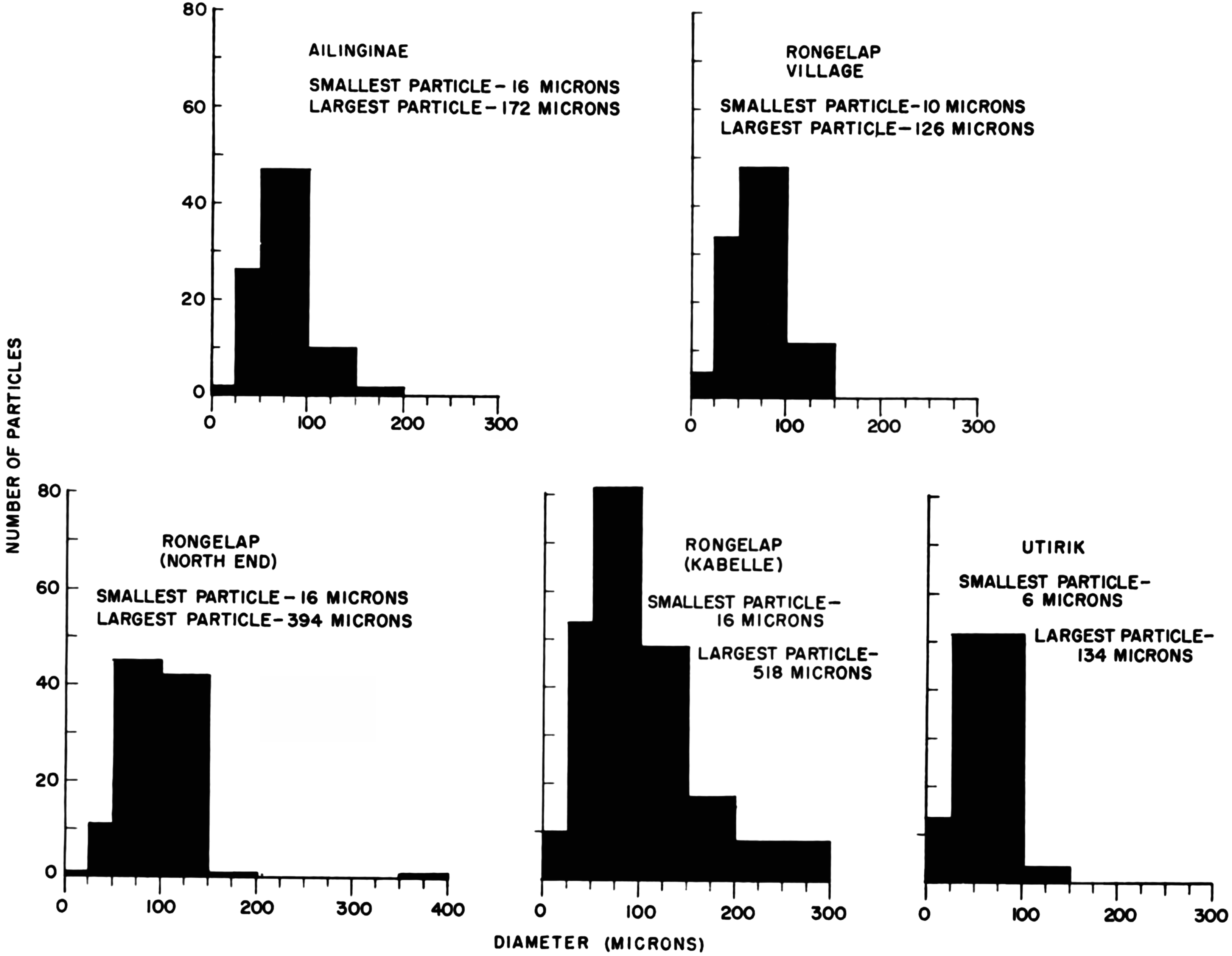


Fig. 5.6 Shot 1, Outer Atoll Particle Size Distribution

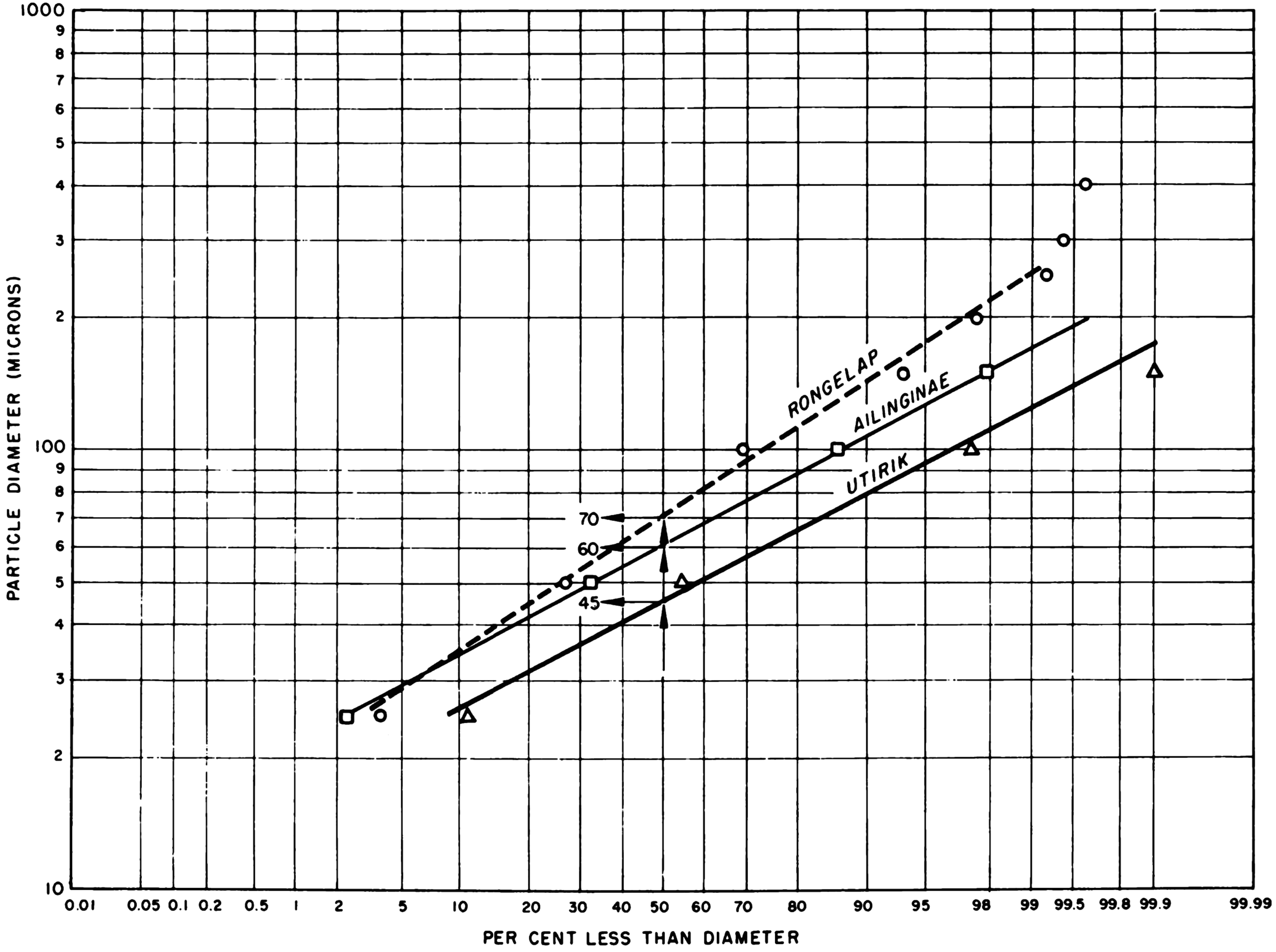


Fig. 5.7 Shot 1, Outer Atoll Cumulative Particle Size Distribution

The fact that the mean particle diameter at Ailinginae is smaller than at Rongelap can be partially explained by analysis of the wind profile which indicates, as one moves south from the axis of symmetry of the fallout pattern, that the particles delivered have smaller diameters (see Chapter 6).

5.2.3 Shot 6, Particle Size

The differential collector stationed on Alice contained visible particulate as well as some liquid; the analysis of particle size distribution is presented in Appendix C. With a total of 321 particles measured the distribution was nearly log normal with a geometric mean diameter of 180 μ as shown in Fig. 5.8. Alice was 3 nautical miles from ground zero.

5.3 RATIO OF ACTIVE TO INACTIVE PARTICLES

One of the most difficult problems to resolve is the ratio of active to inactive fallout particles that arrive at a collecting instrument. This is especially true of the smaller diameter particles because it is extremely difficult to avoid pollution of the sample by extraneous particulate. In this analysis many small inactive particles were observed during the measurement of particle diameters. In many cases these particles were less than 5 μ in diameter. To arrive at a ratio, all particulate was ignored that did not have the characteristic white opaque color of fallout.

Two samples were analyzed from Shot 1 fallout collected at lagoon stations where the effect of island dust pollution was minimized. The results are shown in Fig. 5.9. Approximately 25 per cent of the particles were found to be inactive with the mean particle size of the inactive particles smaller than the active.

5.4 PARTICLE DENSITY

Particles from the Shot 1 lagoon station differential fallout collectors were analyzed to determine their apparent density which is defined as the specific gravity of the particle as a whole. Because of the station locations and the collecting instrument used, these particles had a very high probability of being true fallout. Seventy-nine particles from stations 250.04, 250.17, and 250.24 were measured. Density, average diameter, color, and relative activity were determined for each particle.

Table 5.5 shows the particle density found at each station. The overall average density of the 79 particles was 2.36 g/cu cm with a standard deviation of 8.9 per cent.

Attempts to find relationships between particle size and activity; particle size and density; and density and activity proved unsuccessful. All particle density data are tabulated in Appendix D.

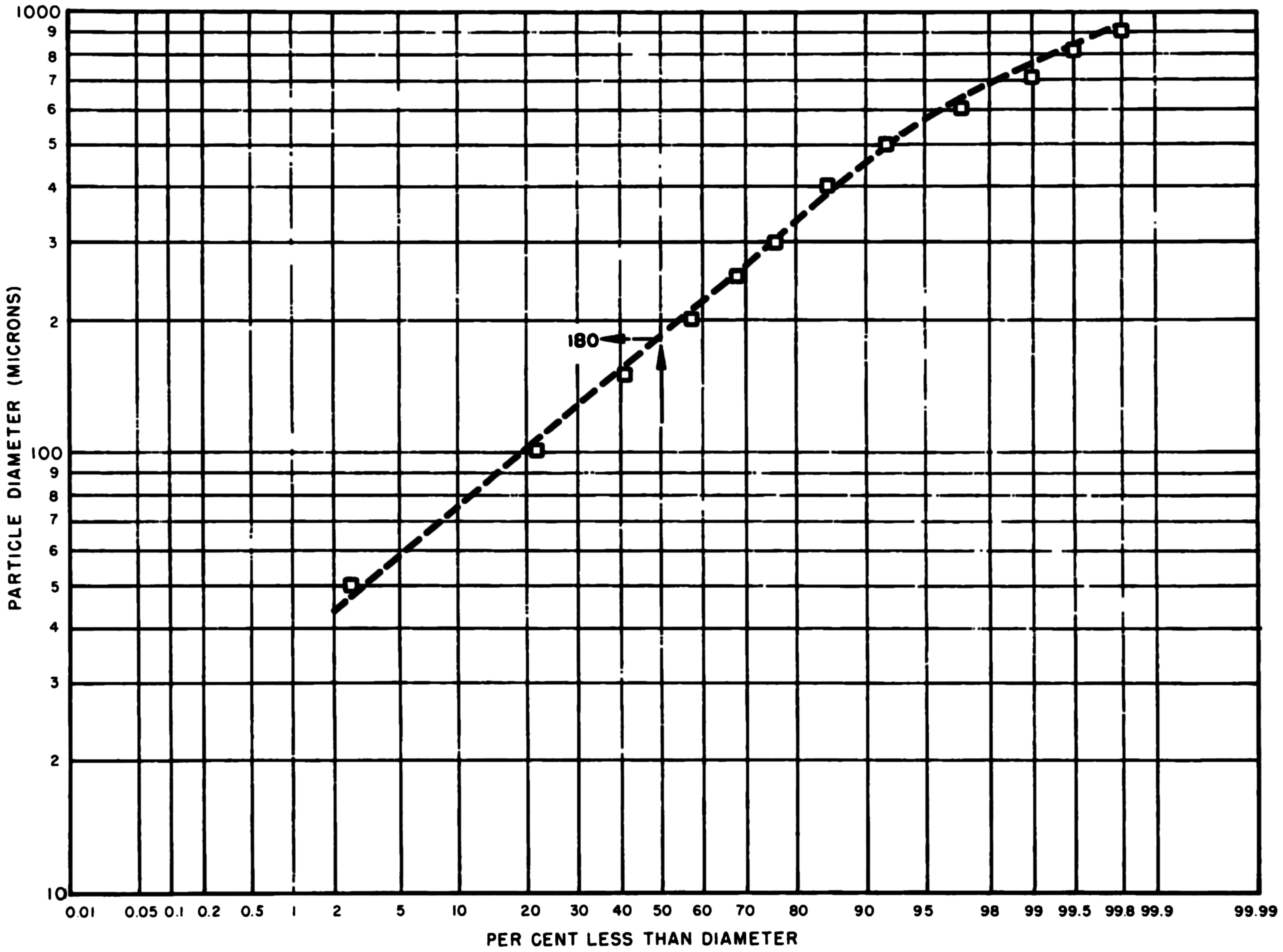


Fig. 5.8 Shot 6, Cumulative Particle Size Distribution, Station Alice

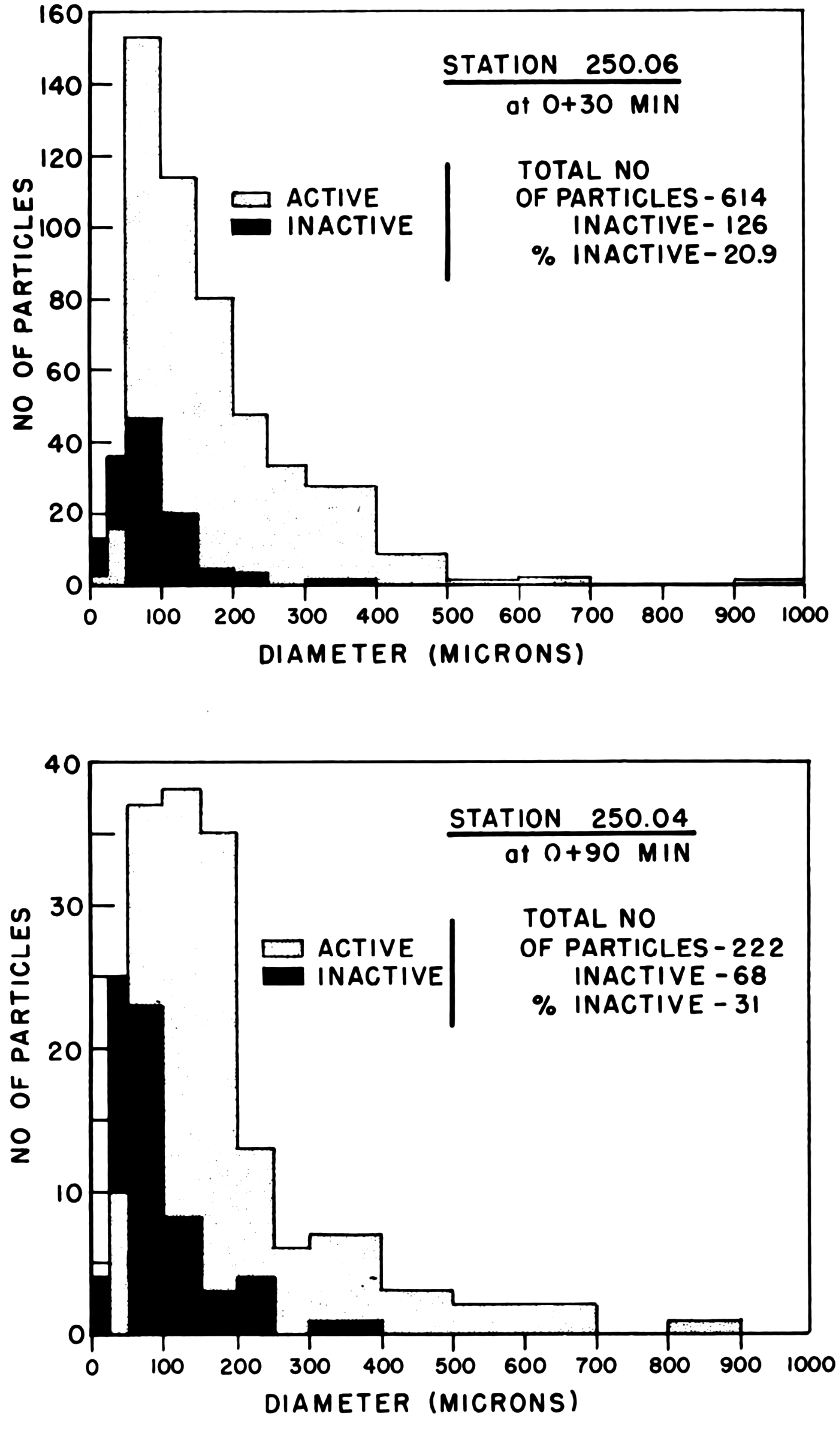


Fig. 5.9 Shot 1, Ratio of Active to Inactive Particles

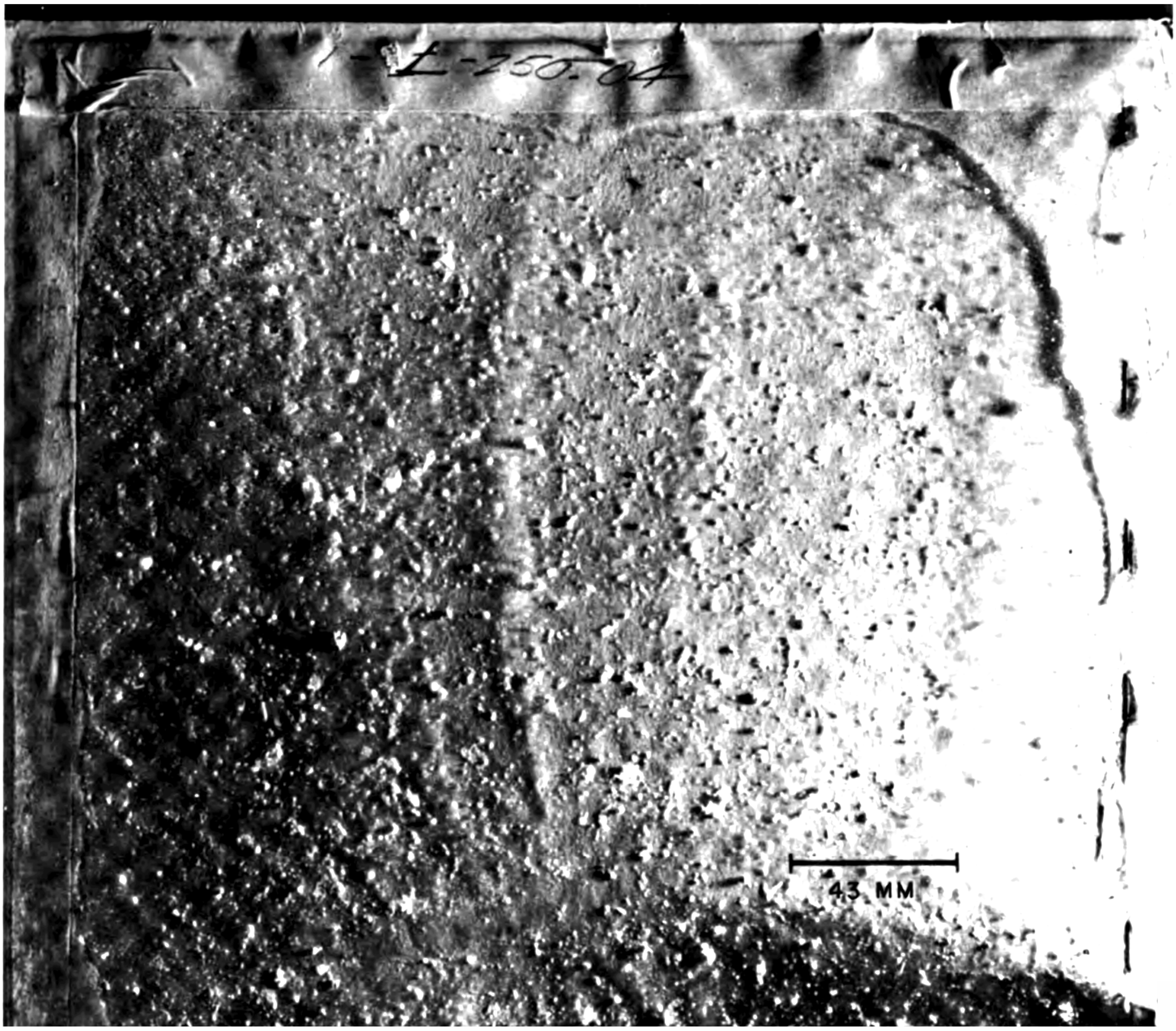


Fig. 5.10 Shot 1, Fallout Particulate, Station 250.04

5.6.1 Shot 1

Fourteen differential fallout collectors were recovered from the land and lagoon stations after Shot 1. Of these, eight had sampled properly and the data therefrom are presented in Appendix C (Figs. C-9 through C-16). Of the 40 sampling increments, Samples 10 and 11, 20 and 21, and 30 and 31 were collected over the same time interval (see points A,B, and C of Figs. C-9 through C-16.) With perfect sampling these increments would collect identical amounts of fallout and the reduced data could then be used to determine not only the period of fallout but also the rate of arrival. However, as indicated from increment groups A,B, and C, the levels of activity varied by as much as an order of magnitude. This variation was undoubtedly the result of sampling small amounts of material over a small area for short time intervals. This deficiency does not affect the usefulness of the instrument in performing its primary function of determining the time of arrival but it does explain the erratic nature of the curves. Relative counts of each increment were made with a gamma scintillation counter under fixed geometry. The level of activity as indicated in Figs. C-9 through C-16 should not be construed as indicative of the rate of arrival of fallout material.

Several differential fallout collectors that failed to trigger were analyzed to determine the field background of the collecting increments. Figure C-17 shows the general level of contamination found in a non-operating sampler located at station 251.09 that was exposed to fallout.

Table 5.6 tabulates time of arrival period and time of cessation of fallout within the Bikini Atoll area. Data collected from Project 2.2 and Project 2.5a time-intensity recorder traces are also presented.

TABLE 5.6 - Time of Arrival of Fallout

Station	Sampler	Time of Arrival (min)	Period (min)	Time of Cessation (min)
250.05	Differential Collector	0 + 20	125	0 + 145
250.06	Differential Collector	0 + 25	115	0 + 140
250.22	Differential Collector	0 + 35	60	0 + 95
250.24	Differential Collector	0 + 25	80	0 + 95
251.04	Differential Collector	0 + 30	125	0 + 155
251.05	Differential Collector	0 + 35	90	0 + 125
251.06	Differential Collector	0 + 25	70	0 + 95
251.10	Differential Collector	0 + 40	50	0 + 90
251.03	Time Intensity Recorder	0 + 15	-	-
Dog	(a)Proj. 2.2	<0 + 15	-	-
Oboe	Proj. 2.2	<0 + 15	-	-

(a) See Reference 2 for an account of this project

Analysis of the gamma time-intensity recorder trace located at How gave the best evidence of the rate of arrival of fallout.

Use of the differential fallout collector and the time-intensity recorder for determining the period of fallout was restricted to the lagoon and islands of Bikini Atoll thereby limiting the distance to 15 nautical miles. The average arrival time within the area was 0 + 28 min with cessation averaging 0 + 117 min resulting in an average period of 89 min. These data compare well with that observed at IVY[7] where the period was somewhat less than 2 hr. Residual fallout which was of such quantity that it contributed little to the overall field was found to deposit for a period of soveral hours after the deposition of the main body of material.

The Bikini Atoll islands along the axis of the fallout pattern experienced fallout over a longer period of time than did those islands located in a crosswise direction.

5.6.2 Shot 2

No evidence was found of primary fallout at early times in the Bikini Lagoon. Secondary fallout of maximum intensity of 40 mr/hr arrived at How Island 37.5 hr after Shot 2, as shown by the gamma time-intensity recorder.

5.6.3 Shot 3

No differential fallout collectors were operative for Shot 3. The gamma time-intensity recorder at How Island indicated a time of arrival of 0 + 38 min. Project 2.2 established an arrival time on Dog Island of approximately 0 + 20 min.[2]

5.6.4 Shot 6

One differential fallout collector located at Alice Island, Eniwetok Atoll, received significant fallout and indicated an arrival time of 0 + 35 min with the period of fallout being 65 min (Fig. C-18).

5.7 RATE OF ARRIVAL OF FALLOUT AND INTEGRATED DOSE

Of the two gamma ionization time-intensity recorders installed on Yoke and How Islands of Bikini Atoll, only the one on How survived and recorded data from Shots 1, 2, and 3. These data give accurate information on rate of arrival of fallout as well as time of arrival.

5.7.1 Rate of Arrival

Table 5.7 presents the time of arrival of fallout and time of peak activity for Shots 1, 2, and 3. The time at which the activity peaks is not the time of cessation of fallout. It is best described as the time at which the rate of decay is greater than the rate of build-up of fallout.

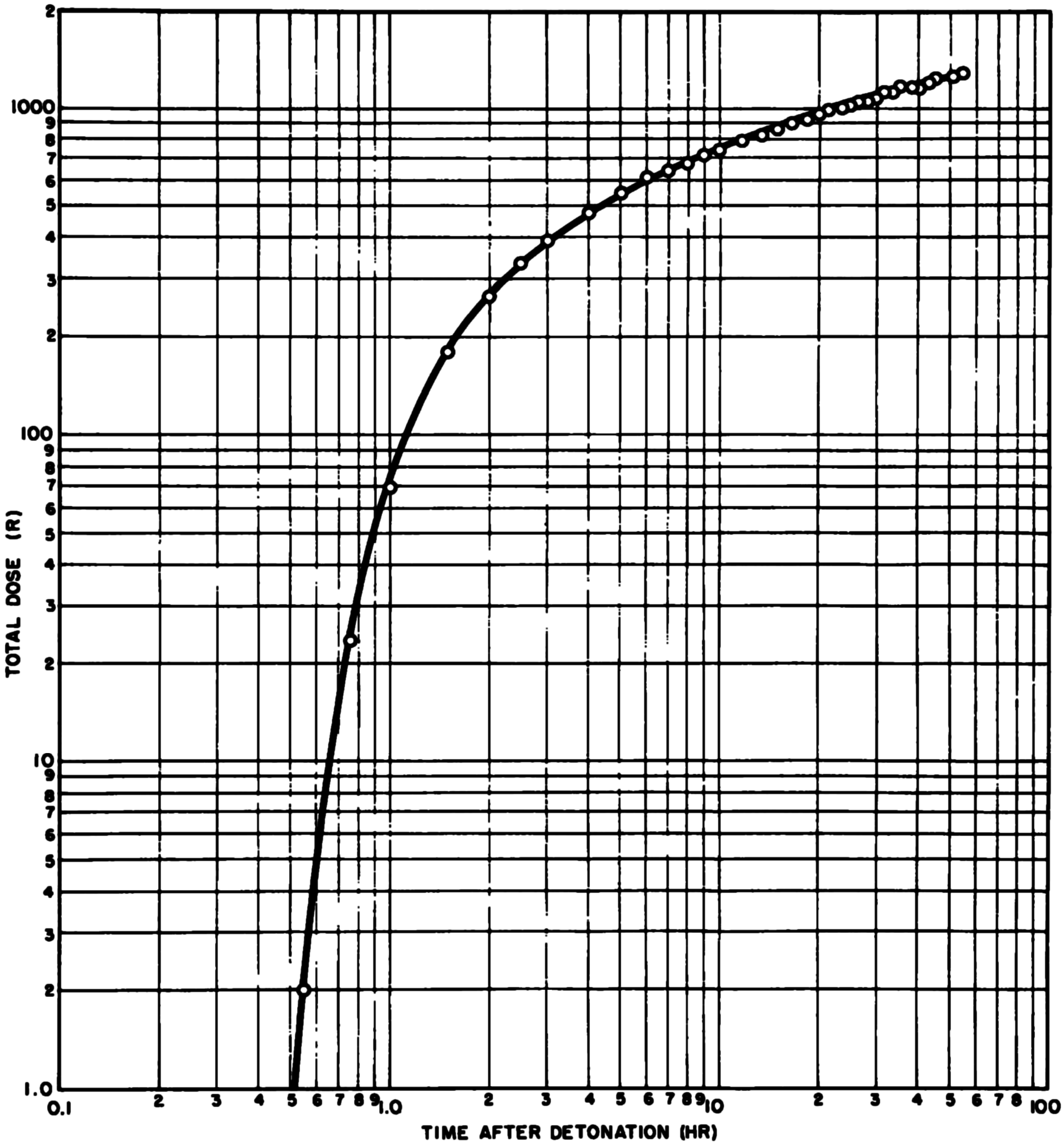


Fig. 5.11 Shot 1, Integrated Gamma Dose, Station 251.03

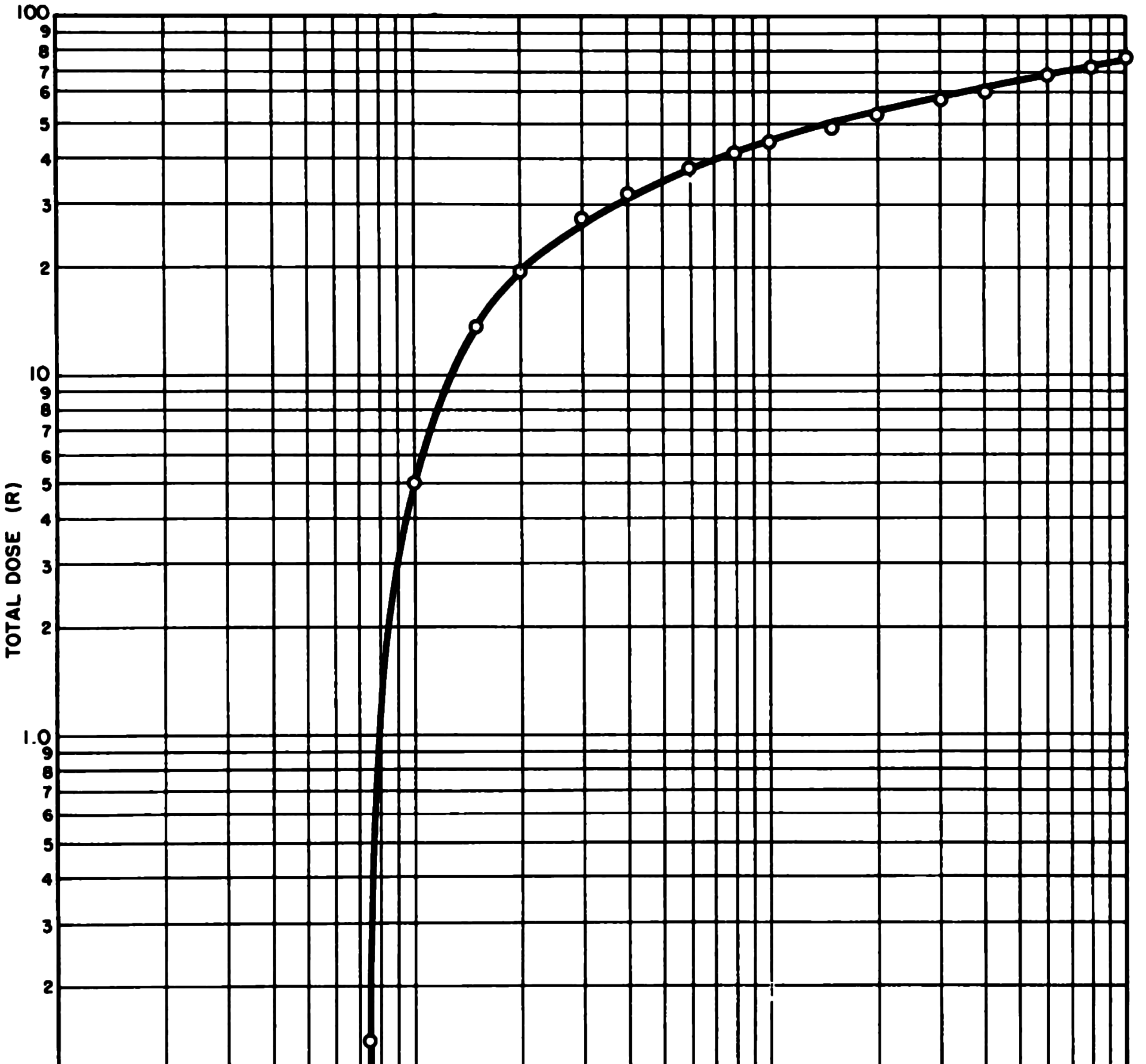


Fig. 5.12 Shot 3, Integrated Gamma Dose, Station 251.03

TABLE 5.7 - Rate of Arrival of Fallout

Shot	Station	Time of Arrival (min)	Time to Peak Activity (min)	Time Between Fallout Arrival and Peak Activity (min)
1	How Island	0 + 15	0 + 65	50
3	How Island	0 + 38	0 + 66	28
2 (secondary fallout)	How Island	0 + 2250	0 + 3280	1030

5.7.2 Total Dose

Figures 5.11 and 5.12 indicate the integrated gamma dose to a time approximately 100 hr after detonation for Shots 1 and 3. Shot 2 deposited only secondary fallout on How Island and the data are not presented.

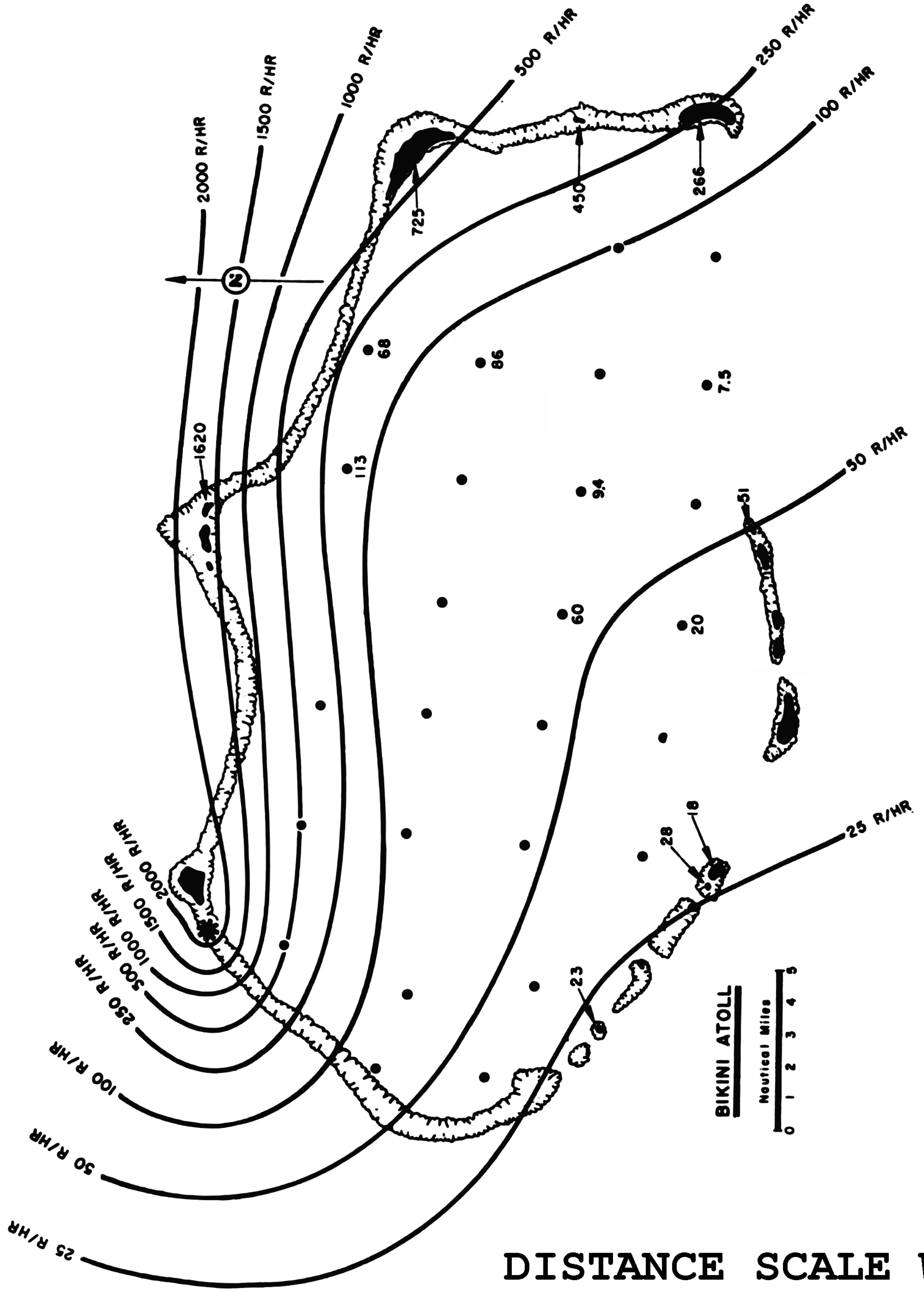


Fig. 6.1 Shot 1, Close-in Gamma Fallout Pattern (r/hr at 1 hr)

DISTANCE SCALE WRONG

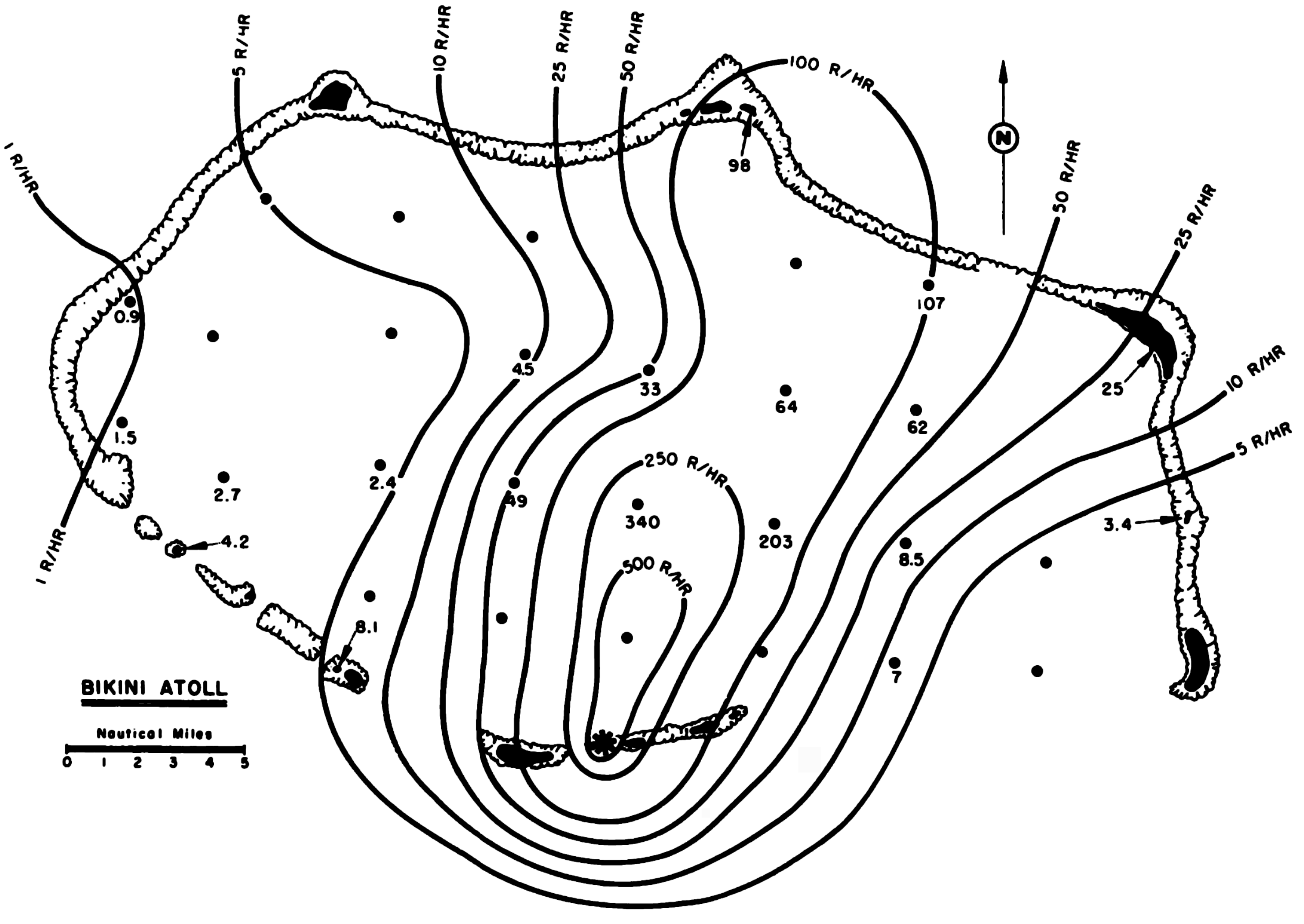
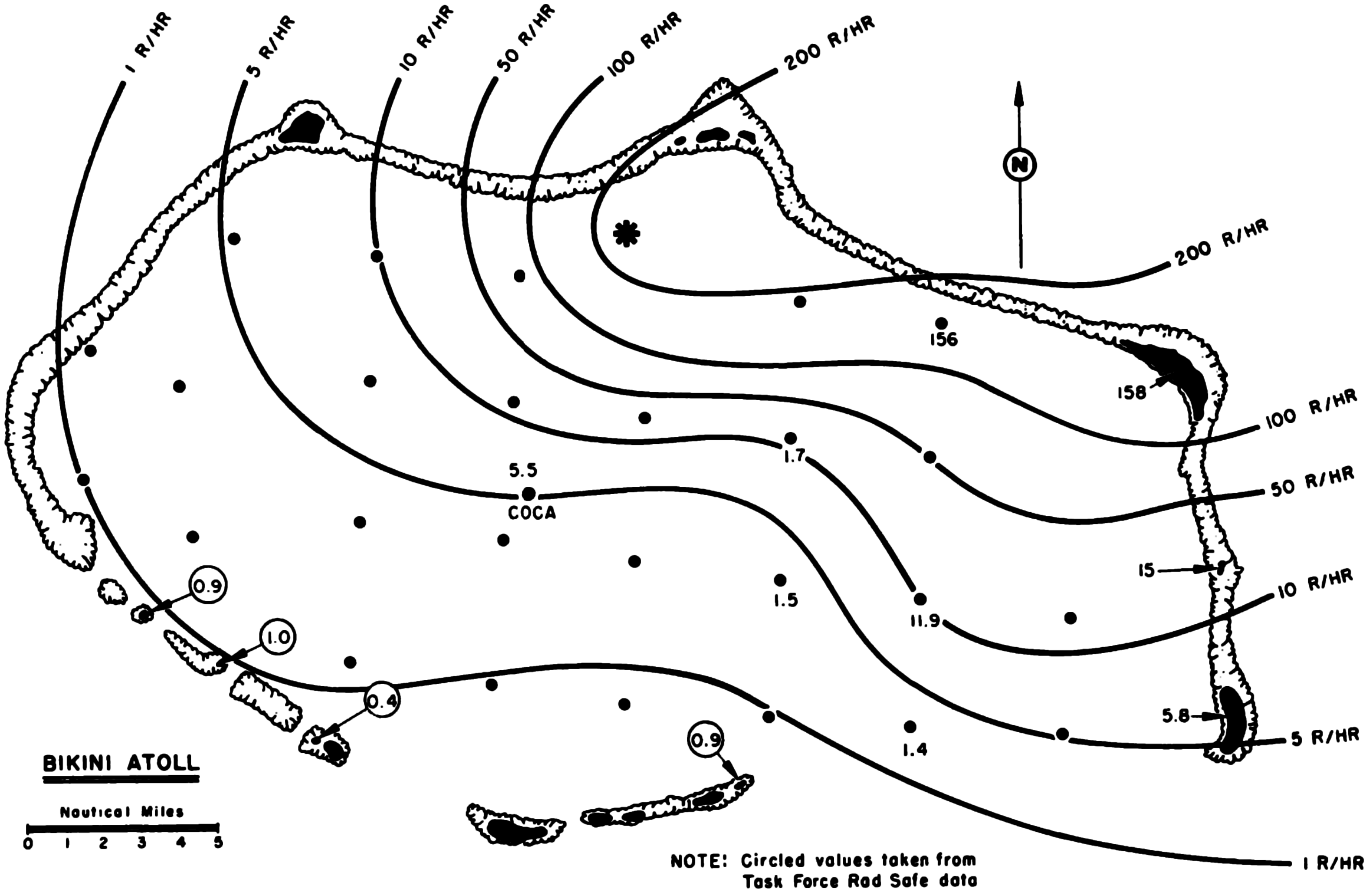


Fig. 6.2 Shot 3, Close-in Gamma Fallout Pattern (r/hr at 1 hr)

DISTANCE SCALE WRONG



NOTE: Circled values taken from
Task Force Rad Safe data

Fig. 6.3 Shot 4, Close-in Gamma Fallout Pattern (r/hr at 1 hr)

DISTANCE SCALE WRONG

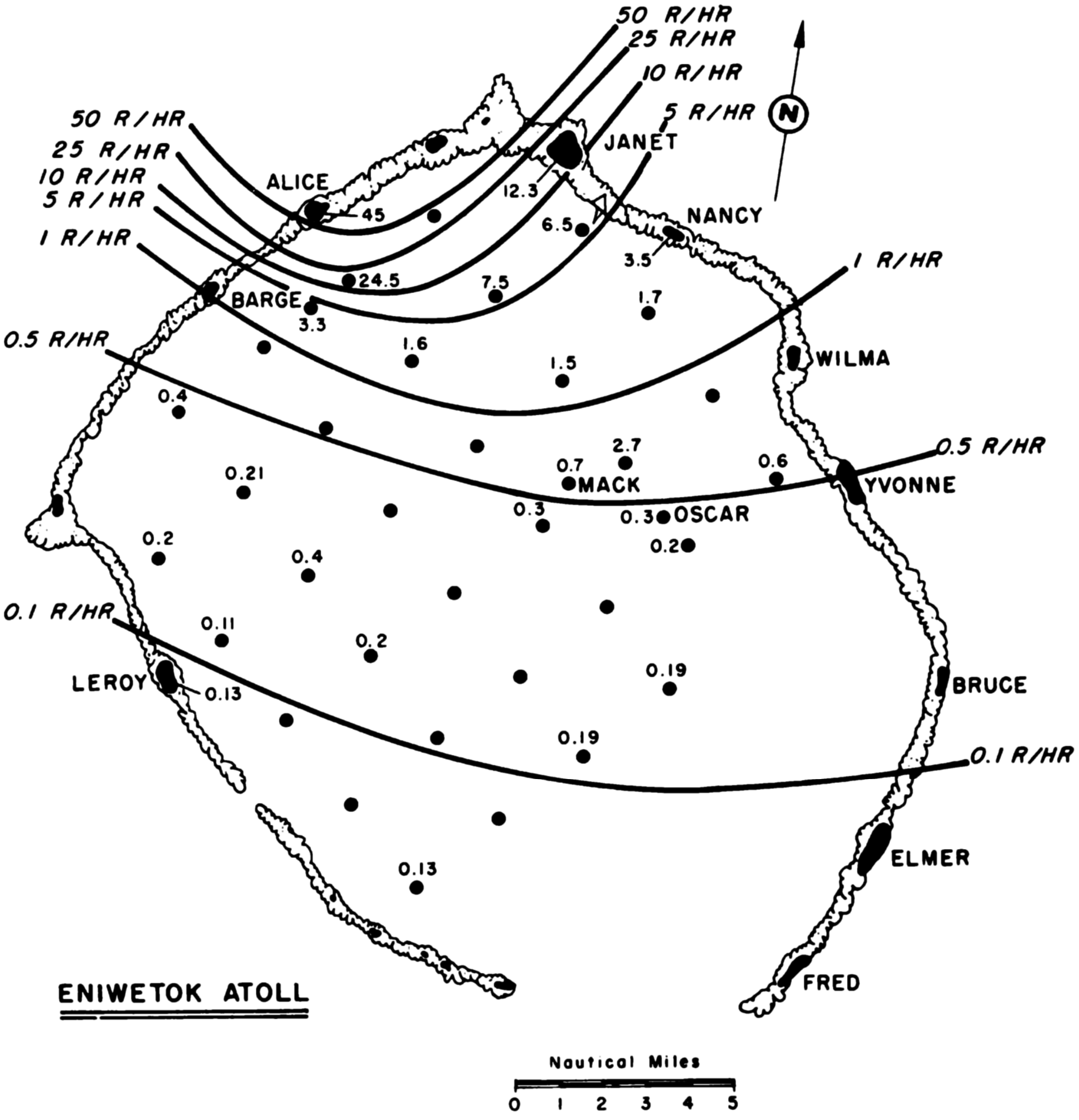


Fig. 6.4 Shot 6, Close-in Gamma Fallout Pattern (r/hr at 1 hr)

DISTANCE SCALE WRONG

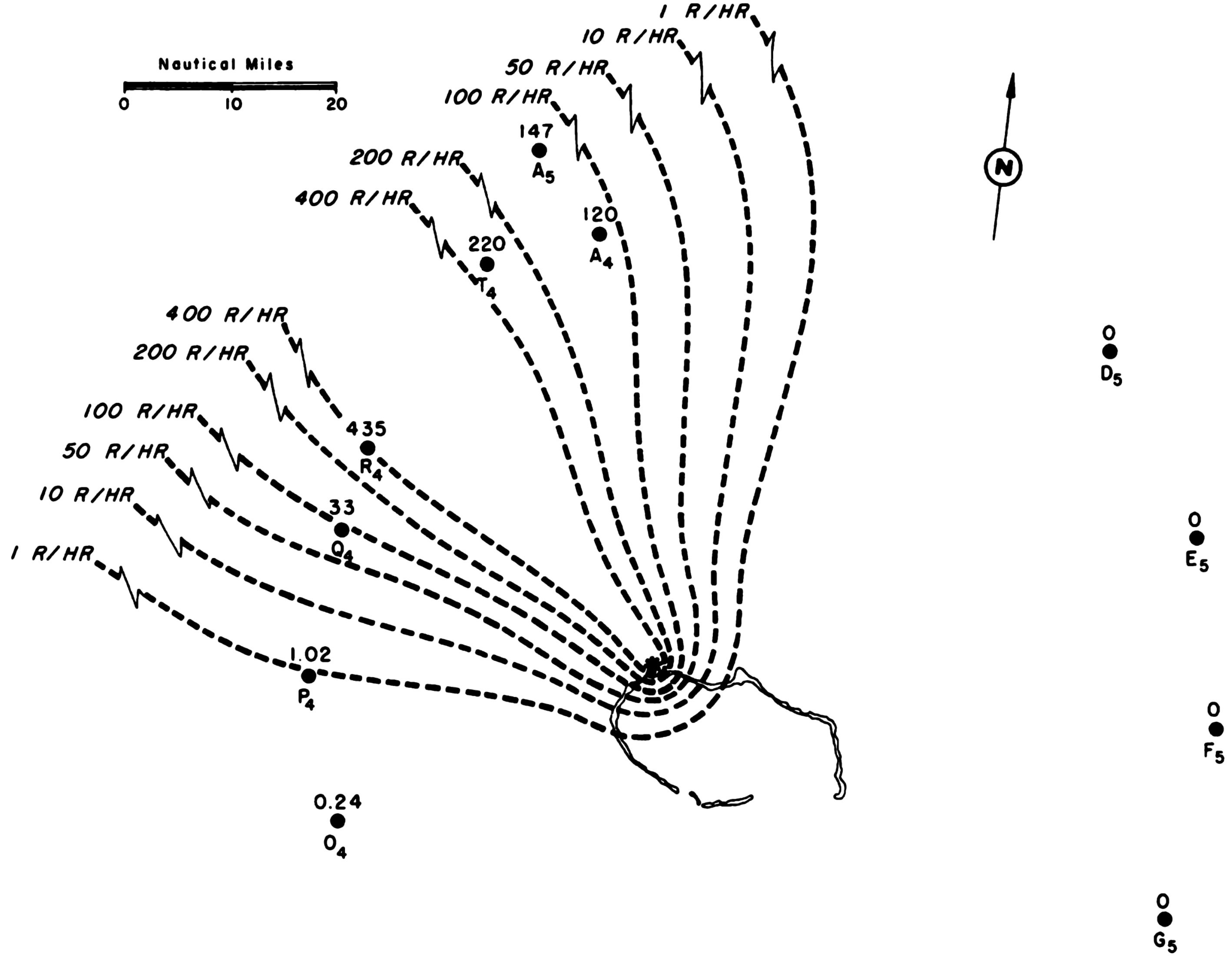


Fig. 6.14 Shot 2, Fallout Pattern (r/hr at 1 hr)

CHAPTER 7

SUMMARY

7.1 GENERAL OBSERVATIONS

The study of thermonuclear explosions at CASTLE has shown the fallout problem to be of considerably greater magnitude than predicted. This demonstration of the radiological capabilities of superweapons makes it imperative that scaling relationships for fallout be derived which will apply over the entire range of possible weapon yields. A common basis of development is required if predictions are to be valid for the now undocumented medium yield range (high yield fission—low yield thermonuclear). Such a basis may be found in the changes in cloud geometry which are known to occur with changes in yield.

The increased coverage by fallout appears to be due to the flattening of the source cloud at high yields in contrast to the more nearly spherical cloud shape of the nuclear model used for the predictions. The following general observations may be drawn concerning fallout from the more diffuse source:

(a) The extent of land gamma radiation fields of military significance is increased beyond that directly attributable to the increase in yield over the nuclear range.

(b) This increase in the area of lethality is the result of a more even distribution of fallout over a larger area. Stating it another way, reduction of the extra-lethal or over-kill factor extends the lethal range for fallout.

(c) The increased efficiency with which superweapons disperse radioactive materials is to some extent counter-acted by the delay in arrival of fallout from the high source cloud and the rapid rate of decay which occurs in the interim.

7.2 PLANS FOR FURTHER WORK

Further study of the interaction of these three factors and comparisons with model data are expected to reveal the part cloud geometry plays in the distribution of fallout. Correlation of data from all CASTLE sources, including the results of water sampling under Project 2.7, will be made using the USNRDL experimental model.

APPENDIX B

GAMMA ACTIVITY MEASUREMENTS FOR THE TOTAL AND GUMMED PAPER COLLECTORS

TABLE B.1 - Gamma Activity Measurements, Shot 1, Total Collectors

Sample No.	Wt. of Solid (g)	Wt. of Liquid (ml)	Gamma Activity (mr/hr)		Date and Time Measured (PST)
			Liquid	Solid	
251.02	28.69	345	79.6	594.8	3/18/54 - 1400
251.03	803	14	8.1	144.5	3/18/54 - 1400
251.04	5.01	4	1.8	65.7	3/18/54 - 1400
251.05	1.61	6	0.91	27.7	3/18/54 - 1400
251.06	1.17	0	0	2.9	3/18/54 - 1400
251.07	0	120	0.9	0	3/18/54 - 1400
251.08	1.25	138	0.13	1.3	3/18/54 - 1400
251.10	3.58	124	0.23	0.96	3/18/54 - 1400
250.04	0.26	40	0.96	7.2	3/18/54 - 1400
250.05	0.14	78	0.58	3.5	3/18/54 - 1400
250.18	0	55	0.13	0.35	3/18/54 - 1400
250.22	0	16	0.058	0.31	3/18/54 - 1400
250.24	0.21	82	0.40	0.64	3/18/54 - 1400

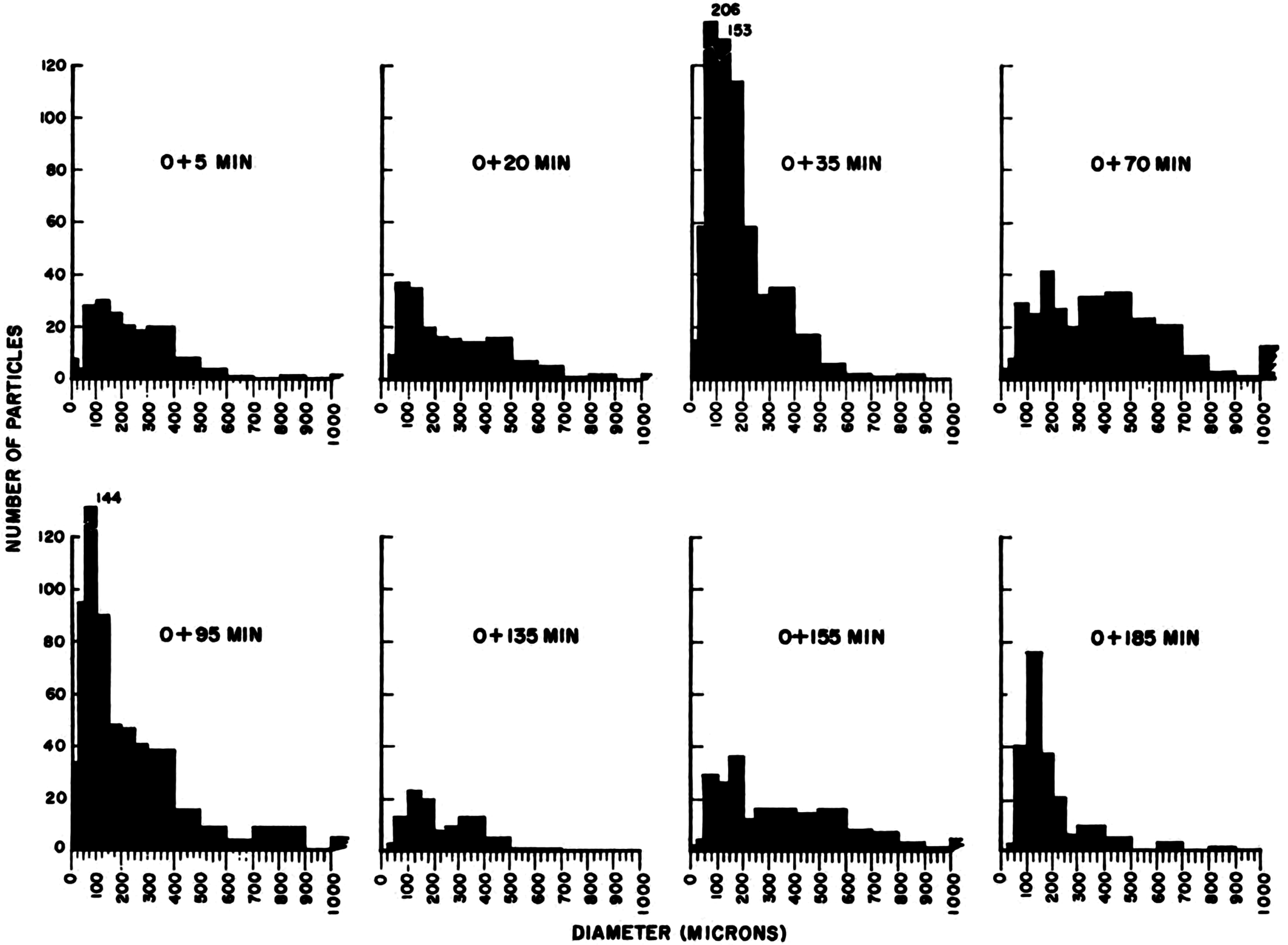


Fig. C.1 Shot 1 Particle Size Distribution, Station 250.04

APPENDIX D

FALLOUT PARTICLE DENSITY, SHOT 1

TABLE D.1 - Differential Fallout Collector 250.04

Sample No.	Sampling Time min after ABD	Density (g/cu cm)	Average Diameter (μ)	γActivity (c/m)	Date Counted	Color
1	25	2.28	1480	53	7/20	white with orange tinge
2	40	2.05	1020	84	7/20	white
3	40	2.54	900	86	7/19	grayish white
4	50	2.24	580	89	7/20	white
5	55	2.22	730	210	7/20	white
6	75	2.42	1060	110	7/19	gray
7	80	2.26	810	230	7/19	white
8	85	2.52	350	21	7/20	white
9	90	2.52	750	47	7/23	white
10	95	2.18	675	502	7/20	white
11	100	2.17	550	66	7/19	white
12	105	2.10	500	40	7/21	white
13	110	2.24	630	0	7/21	white
14	125	2.19	590	105	7/21	white
15	130	2.41	540	64	7/21	white
16	135	2.22	260	19	7/21	white
17	130	1.78	490	13	7/19	white
18	140	2.18	350	44	7/21	white
19	140	2.35	590	84	7/21	white
20	140	2.21	530	231	7/21	white
21	145	2.23	310	34	7/21	white
22	145	2.40	480	36	7/21	white
23	145	2.04	650	106	7/21	white
24	150	2.38	340	61	7/22	white
25	160	2.27	380	64	7/22	white
26	160	1.94	700	99	7/23	white
27	160	2.38	515	62	7/23	white
28	165	1.65	620	66	7/23	white
29	165	2.10	375	2	7/23	white
30	170	2.67	570	13	7/19	white
31	175	2.32	325	44	7/19	white
32	185	2.20	325	24	7/19	white

TABLE D.2 - Differential Fallout Collector 250.17

Sample No.	Sampling Time (min after ABD)	Density (g/cu cm)	Average Diameter (μ)	γ Activity (c/m)	Date Counted	Color
1	5	2.42	800	61	7/28	grayish
2	10	2.52	820	461	7/28	white
3	10	2.50	830	13	7/28	white
4	10	2.39	460	26	7/28	white
5	15	2.22	330	163	7/28	white
6	15	2.66	840	55	7/28	gray
7	20	2.40	525	14	7/28	gray
8	25	2.51	480	27	7/29	gray
9	35	2.55	360	38	7/29	gray
10	40	2.46	260	0	7/29	gray
11	40	2.55	1750	20	7/29	white with brown tinge
12	40	2.52	480	0	7/29	white
13	45	2.44	680	54	7/29	white
14	50	2.37	425	6	7/29	white
15	50	2.33	350	0	7/29	white
16	50	2.36	610	0	7/29	white
17	50	2.54	320	0	7/28	white
18	50	2.01	900	127	7/29	white
19	50	2.71	440	4	7/28	white
20	50	2.38	640	0	7/28	white
21	95	1.95	560	0	7/28	white
22	110	2.47	600	10	7/28	white
23	135	2.47	530	13	7/28	white
24	135	2.49	770	5	7/28	white
25	160	2.45	300	17	7/29	white
26	175	2.34	470	2928	7/29	white

TABLE D.3 - Differential Fallout Collector 250.24

Sample No.	Sampling Time (min after ABD)	Density (g/cu cm)	Average Diameter (μ)	γ Activity (c/m)	Date Counted	Color
1	5	2.11	420	0	7/22	white
2	10	2.40	980	0	7/22	white
3	15	2.38	425	0	7/22	white
4	20	2.22	240	26	7/22	white
5	25	2.75	275	12	7/22	white
6	35	2.66	675	160	7/22	white
7	50	2.62	1410	146	7/23	white
8	60	2.46	335	0	7/23	white
9	65	2.38	220	0	7/23	white
10	65	2.54	535	33	7/23	white
11	65	2.55	440	42	7/23	white
12	65	2.60	340	43	7/23	white
13	65	2.59	250	65	7/23	white
14	65	2.48	250	44	7/23	white
15	65	2.36	590	141	7/23	white
16	80	2.58	200	7	7/23	white
17	90	2.45	270	31	7/23	white
18	150	2.05	310	24	7/23	white

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